Loss of shell effects at finite rotational frequency

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We have tried to understand in a systematic way the contribution of shell effects to nuclear moments of inertia at high spins, both at zero and finite temperature. These shell effects are manifested in the deviation of the moments of inertia from the rigid-body values and by non-zero shell energies. The semiclassical Periodic Orbit Theory (POT) calculates these shell effects in terms of contributions from classical periodic orbits in a spheroidal cavity of the same shape as that of the nucleus. POT is ideally suited for this since the contributions of only the shortest orbits (triangles and rhombi) are sufficient to understand the variations with neutron number of the quantities of interest, making it possible to extract generic features (e.g., dependence on shape). Strutinsky-type shell energies as well as deviations from rigid-body moments of inertia (i.e., shell moments of inertia) are calculated both semiclassically and quantum mechanically and have been shown [1] to fit the experimental values.

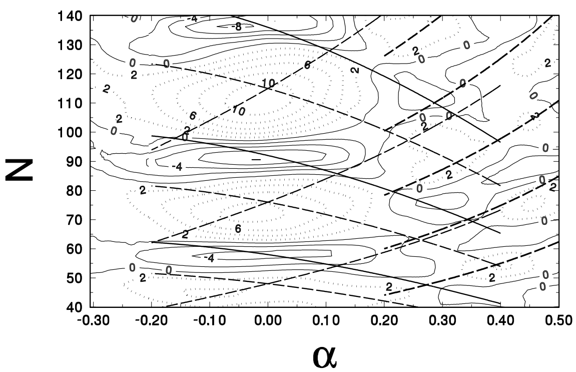

FIG. 1: Shell energy at rotational frequency 0.3 MeV.

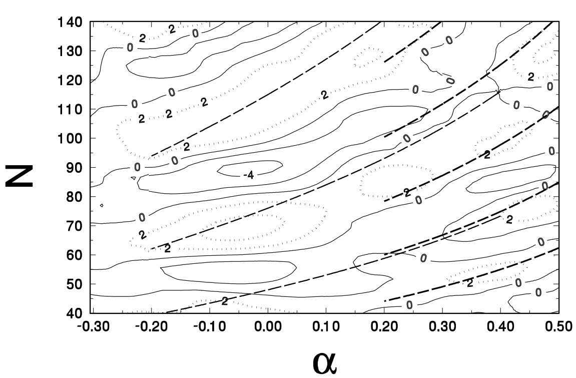

FIG. 2: Shell energy at rotational frequency 0.6 MeV.

We show that the rotation 'damps the shell effects'. The shell energies are calculated for a cavity as a function of deformation α (close to ε) and neutron number N for rotational frequencies of 0.3 MeV (Fig. 1) and 0.6 MeV (Fig. 2) . The contour plots are from quantum mechanical calculations (cranked Woods-Saxon potential with very small diffuseness). The lines are obtained from POT for the rhombi. The downsloping solid (dashed) lines are the loci of minimum (maximum) shell energies from orbits in the planes containing the symmetry axis (meridian, or mr). These orbits are the main contributors to the shell effects, i.e., the structure at 0.3 MeV is dominated by the downsloping lines. In contrast, the structure at 0.6 MeV is clearly dominated by the upsloping lines, which are for equatorial (in plane $\perp$ to the symmetry axis) orbits (eq). POT predicts that this is precisely the effect of the rotation [1], i.e., the main shell effect is destroyed.

The reason is that the orbits (mr) that contribute to the shell moments inertia at frequency ω tend to reduce the shell energy at spin 0 ($E_{sh}(\omega=0)$), so that the shell energy at frequency ω is: $E_{sh}(\omega) = E_{sh}(\omega=0) - (\omega^2/2)\mathcal{J}_{shmr}$. The contribution to the shell energy of the other orbits remains the same. In most of the nuclei, it is the meridian orbits that contribute to the shell moments of inertia because they are the ones enclosing the rotational flux. This explains why only the contribution of the equatorial orbits remain.

Extracted from ref. [1].

REFERENCES

[1] M. Deleplanque, S. Frauendorf, V.V.Pashkevich, S. Chu, and A. Unzhakova, Phys. Rev. C **69**, 044309 (2004).